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US 4326203 A US 4067016 A US 4012741 A
International Journal of Infrared and Millimetre Waves, 7, No 4, 1986. pp550-570. IEEE Transactions on Antennas and Propagation AP-31, No 3, May 1983, pp 406-412.

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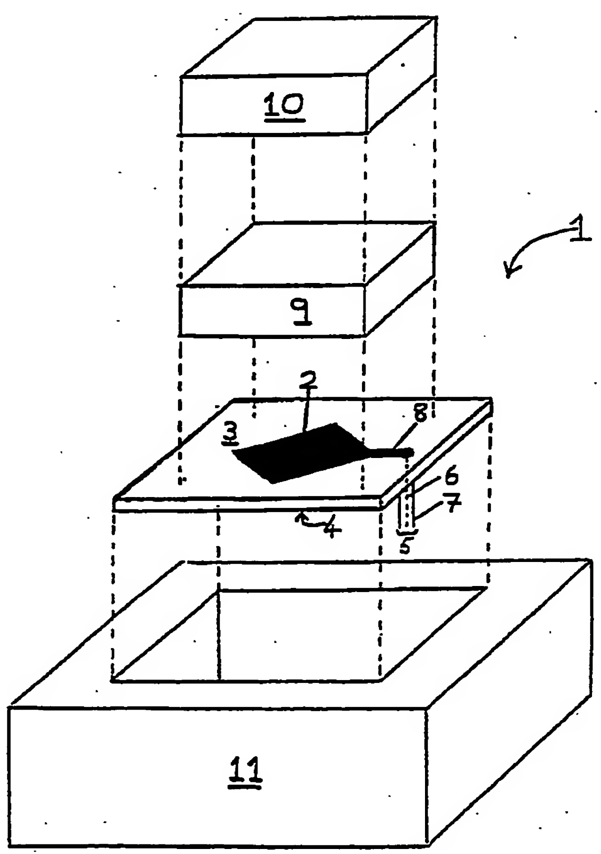
(54) Dielectric resonator antenna.

(57) A dielectric resonator antenna 1 which exhibits a wide bandwidth is achieved by chosing a patch antenna 2 dielectric resonator 9 combination with shape and dimensions such that resonance modes over a continuous range of wavelengths can be established therein. The patch antenna may be square and corner-fed by a planar feed 8. A dielectric element 10 may be provided on the upper face of the dielectric resonator 9, the antireflection characteristics of element 10 being optimised for a wavelength which is slightly different from the maximum wavelength of the patch antenna.



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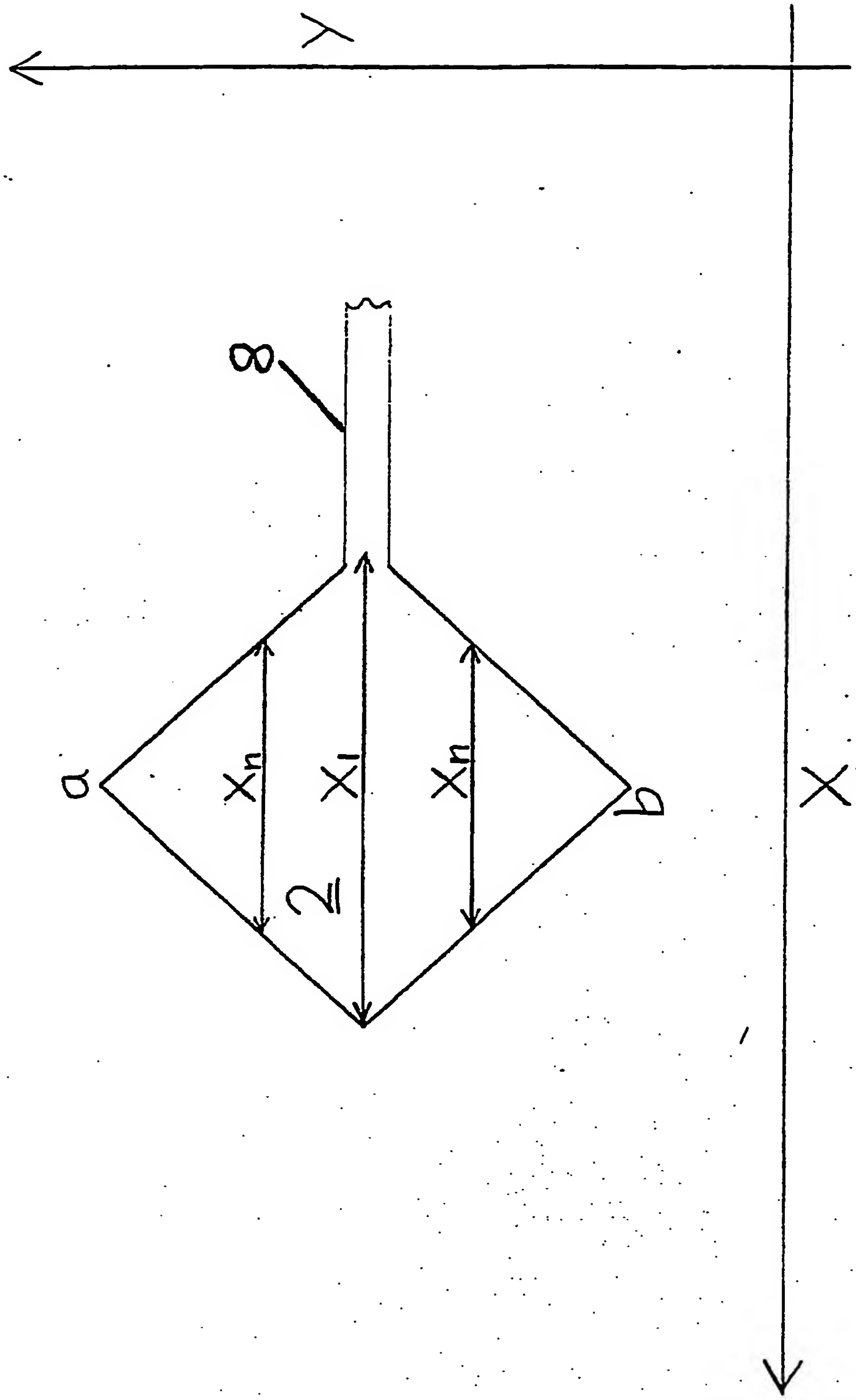

FIGURE 1

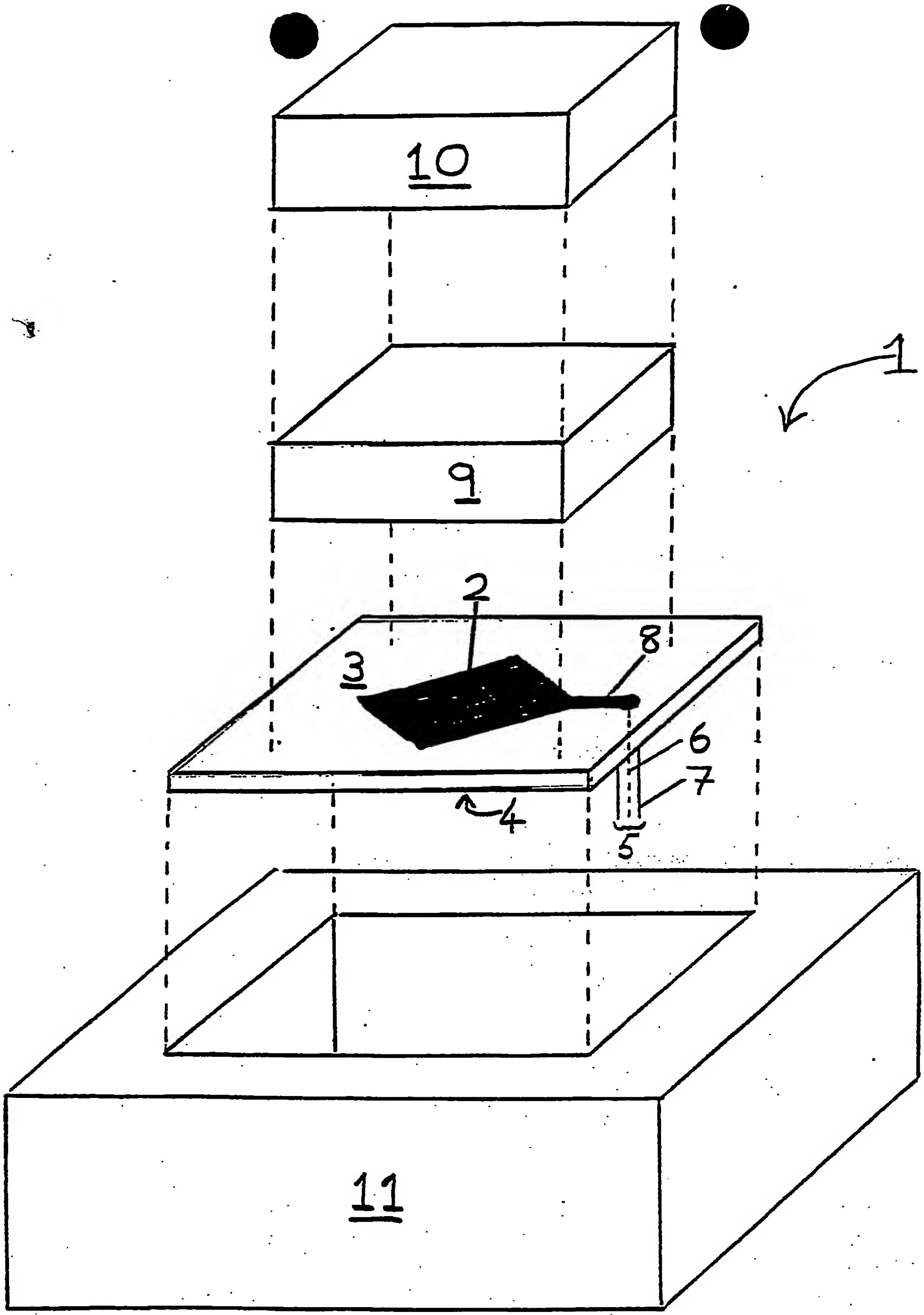

FIGURE 2

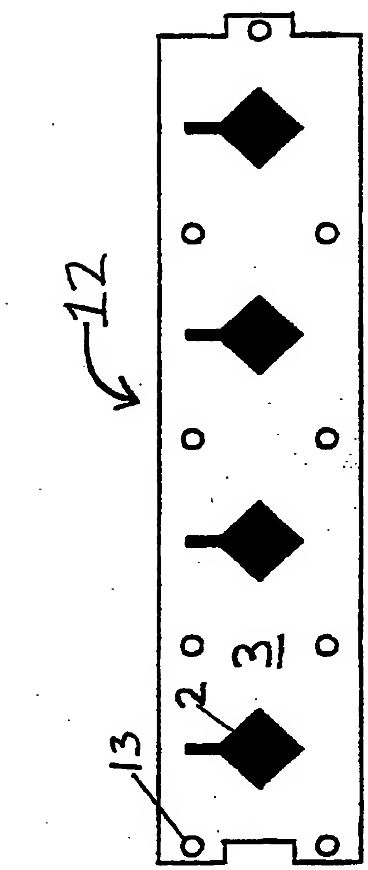

FIGURE 3a

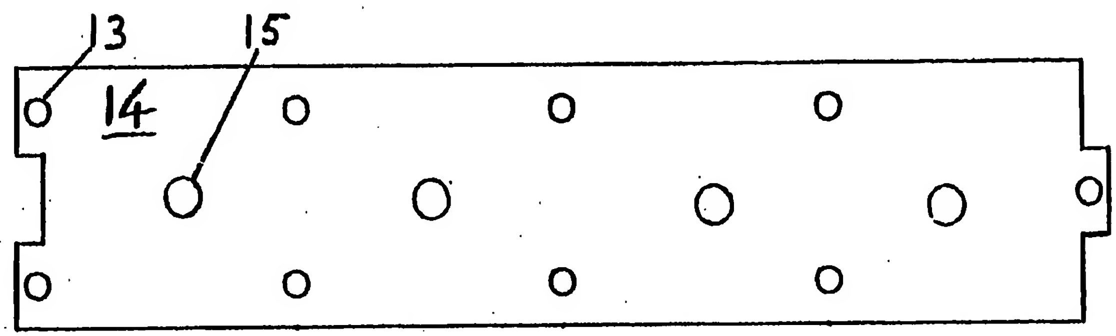

FIGURE 3b

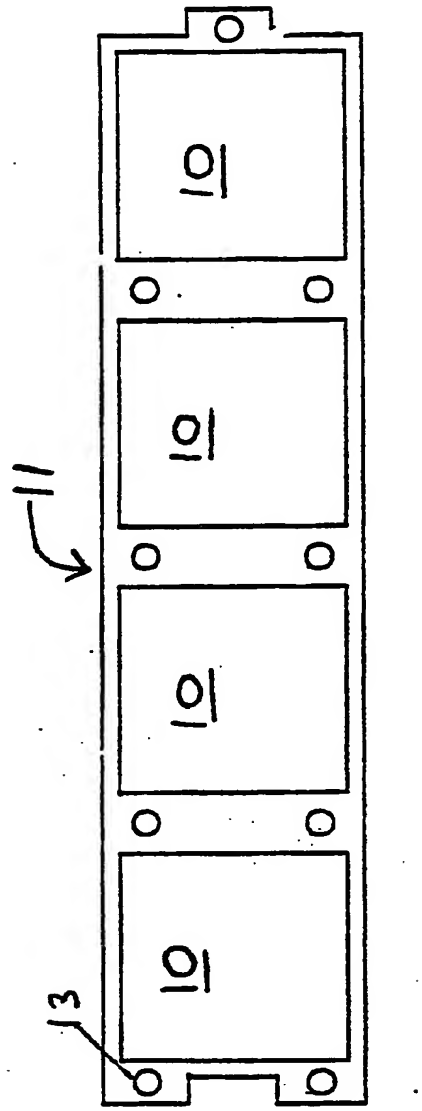

FIGURE 3c

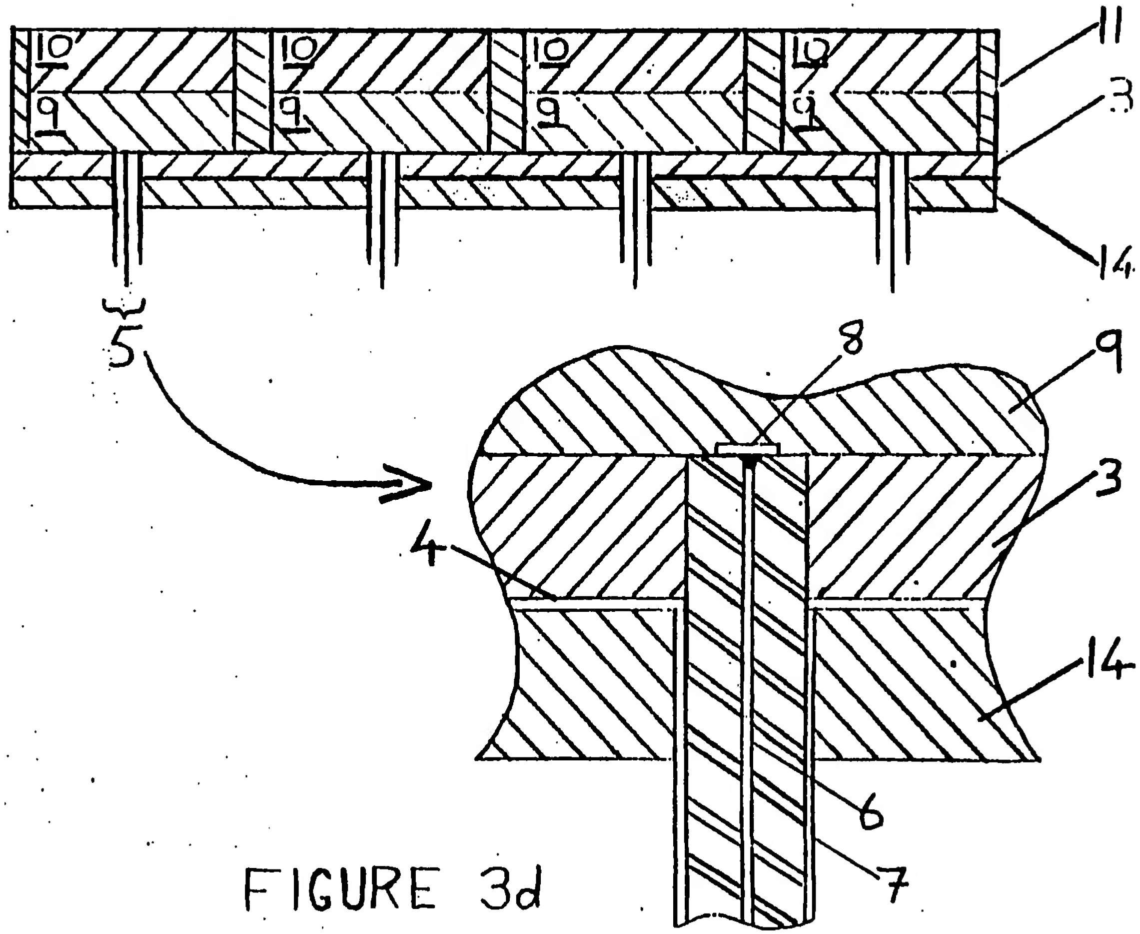

FIGURE 3d

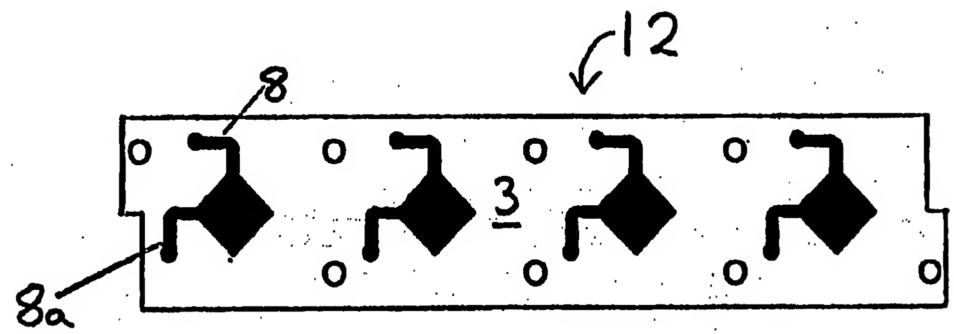

FIGURE 4

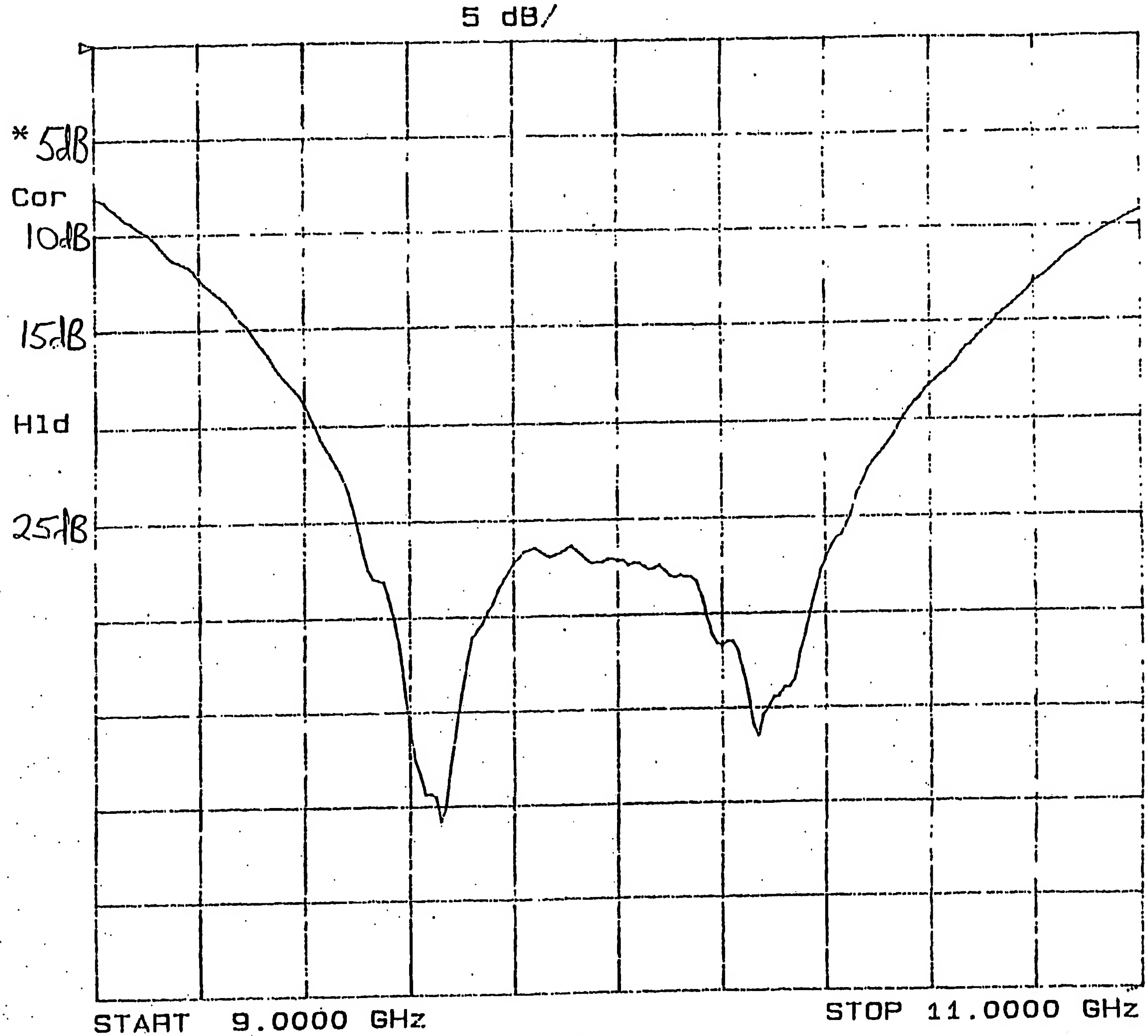
5 dB/
* 5dB
Cor
10dB
15dB
H1d
25dB
START 9.0000 GHz
STOP 11.0000 GHz

FIGURE 5

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DIELECTRIC RESONATOR ANTENNA WITH WIDE BANDWIDTH

This invention relates to a dielectric resonator antenna system with wide bandwidth and, in particular but not exclusively to, such a system for use as an element in a phased array.

The dielectric resonator antenna is well known. It may be probe fed (eg S A Long, M W McAllistar and L C Shen; IEEE Transactions on Antennas and Propagation AP-31, No 3, May 1983, pp406-412 and S A Long and M W McAllistar; International Journal of Infrared and Millimetre Waves, 7, No4, 1986, pp550-570) where the probe has length approximately equal to one quarter of the operating wavelength, and is used to excite a fundamental mode in a coupling block which takes the form of a dielectric puck. The dimensions of the puck are such that it resonates at a specific frequency, this frequency being determined, to a large extent, by the overall volume of the puck.

Alternatively the coupling block may be excited using a patch antenna formed from microstrip, a form of waveguide comprising a copper strip separated from a groundplane by a dielectric substrate. The copper strip is etched to leave an antenna of the required shape and size, typically a square patch fed at the centre of one edge and with the length of each edge equal to half the operating wavelength. Such antennae have the advantage that they occupy little space and can be conveniently connected to form thin planar arrays.

In an array, each element has its own input and output and by varying the phase of the signal at each element the array can be arranged to transmit or receive in a chosen direction. Moreover the chosen direction can be made time dependant so that a given field can be scanned.

At the interface between the coupling block and air, some of the signal is reflected rather than transmitted. This loss of power can be minimised by including an antireflection layer between the dielectric layer and the air (eg British Patent Application 9117629.7). In order to minimise reflection between two media, the thickness of the antireflection layer should approximate to a quarter wavelength of the signal being transmitted. In addition the material of the antireflection layer should (in theory) have a dielectric constant which approximates to the geometric mean of the dielectric constants of the media on either side. In practice, considerable departure from this ideal is acceptable: for example, for matching between air (dielectric constant = 1) and a coupling block of material with dielectric constant = 10 the ideal matching material would have a dielectric constant of 3.16. In practice it is found that polymethylmethacrylate with a dielectric constant of 2.4 serves adequately as a matching material.

Although the foregoing configurations are relatively simple, their use is limited by the inherently narrow range of frequencies over which they can be operated (ie their inherently narrow bandwidth). For example, H LI and C H CHEN describe a probe fed antenna with bandwidth of approximately 200 MHz at 20 dB in Electronics Letters vol. 26 No. 24 (22 November 1990) pp2015-2016. The object of this invention is to provide a dielectric resonator antenna with wide bandwidth.

According to this invention the bandwidth of a dielectric resonator antenna is greatly enhanced by an appropriate choice of shape for the exciting patch. Specifically it has been shown that if a patch is chosen whose length varies along its width, then a wide range of resonant frequencies can be stimulated therein. Furthermore it has been shown that by employing an antireflection block whose optimum frequency is close to, but slightly different from, the minimum frequency of the patch (typically 5% less), the bandwidth and transmission properties of the device are further improved.

According to this invention, a dielectric resonating antenna system comprises

- a dielectric substrate sheet having opposing first and second surfaces; a patch antenna formed on the first surface, the patch antenna having a length that varies across the width of the patch such that a wide range of resonant frequencies can be stimulated therein,

- a ground plane formed on the second surface,

- means for feeding signals to and, or from the patch antenna,

- a dielectric coupling element adjacent to the first surface whose dielectric constant and thickness are such that radiation coupling to and from the probe is predominantly through itself.

In a preferred embodiment, the antenna takes the form of a square, corner-fed patch which is formed on microstrip using the same photo-etching techniques that are standard for making other microwave integrated circuits. An additional advantage of this configuration is that it readily lends itself to implementation of orthogonal planes of polarization which will be described later. Other shapes of patch antenna may also provide these properties of enhanced bandwidth and facilitation of orthogonal planes of polarisation.

The coupling element has dielectric constant of approximately 10 and thickness approximating to a quarter of the device operating maximum wavelength.

The preferred means for feeding signals to and, or from the patch antenna is via a coaxial feed through the groundplane and dielectric substrate.

An additional preferred embodiment includes a dielectric antireflection layer whose dimensions are chosen to provide quarter wavelength antireflection characteristics for an optimum wavelength which is slightly different from the maximum operating wavelength of the patch antenna.

These components may be enclosed in an open-ended metal cavity which constrains the radiating field to that of an aperture rather than a volume.

Embodiments of the device will now be described, by way of example only, with reference to the accompanying diagrams in which :-

Figure 1 is an example of the shape of antenna which provides the wide bandwidth properties of the invention.

Figure 2 is an exploded view of a typical antenna system of the invention in disassembled form.

Figures 3a, 3b and 3c show the component parts making up a four element sub-array, where each element comprises an antenna system of the invention.

Figure 3d shows a cross-section of the sub-array assembly. Larger arrays (typically around 2000 elements) are formed by combining a number of sub-arrays such as this.

Figure 4 shows part of an array of patch antennas of the invention with the implementation of orthogonal planes of polarisation.

Figure 5 shows the range of frequencies over which a typical antenna system of the invention was found to be useful.

Figure 6 shows the E-plane and H-plane radiation patterns obtained from a typical antenna system of the invention.

Figure 1 shows a square, corner fed patch antenna 2, fed by a planar feed 8. In this orientation, the maximum value of the `X' dimension of the patch is $x_1$ between opposite corners of the antenna. As the line through which this dimension is taken moves in the `Y' direction away from this starting point, the value of the `X' dimension decreases through intermediate values $x_n$ to zero at the points a and b. Thus the length of the patch (in the `X' direction) varies across its width (in the `Y' direction).

Figure 2 shows an antenna system 1 of the invention. An antenna of microstrip construction takes the form of a square planar corner-fed patch 2 mounted on a dielectric layer 3. A ground plane 4 clads the underside of the dielectric layer 3. A coaxial radio frequency feedthrough 5 has an inner conductor 6 and an outer shield 7. The inner conductor 6 is insulated from the dielectric layer 3 and is connected to a planar feed 8 into the corner of the patch antenna 2. The outer shield 7 is connected to the ground plane 4.

A dielectric coupling block 9 is located flush against the patch antenna 2 and the top side of the dielectric layer 3. This block 9 is present for radiation purposes and is of PT10, a proprietary material manufactured by Marconi Electronic Devices Ltd., a British company. It is composed of a mixture of alumina and titanium dioxide ceramic materials bound by polystyrene and has a dielectric constant of 10. The thickness of the coupling block approximates to one quarter of the centre frequency of the patch antenna and its overall dimensions are chosen to provide optimum resonance at that frequency.

A second dielectric block 10 is located flush against the top side of the coupling block 9. This second block 10 is present for antireflection purposes and is of polymethylmethacrylate with a dielectric constant of 2.4. It has thickness approximately equal to, but different from, one quarter of the maximum wavelength of the patch antenna.

The assembly of the dielectric substrate 3 with ground plane 4 and patch antenna 2, dielectric coupling block 9 and dielectric antireflection block 10, are held within an open-ended metal casing 11.

Figure 3a shows a plan view of an array 12 of four square-planar corner-fed patch antennas 2 on a dielectric substrate 3. The underside of the substrate 3 is clad by a copper groundplane (not shown). Holes 13 accommodate retaining screws (not shown).

Figure 3b shows a brass backplate 14 which is assembled flush against (and in electrical contact with) the groundplane of the dielectric substrate 3 shown in figure 3a. Holes 13 are tapped to accommodate retaining screws (not shown). Holes 15 each accommodate a coaxial feedthrough (not shown). The inner conductors of these feedthroughs are insulated from the brass backing plate 14, the dielectric substrate 3 and groundplane, and pass through these to connect with the planar feeds 8 shown in figure 3a. The outer shields of the coaxial feedthroughs are connected to the brass backing plate 14.

Figure 3c shows a stainless steel block 11 which is mounted on top of the dielectric substrate shown in figure 2a. Four windows 10 are of transparent polymethylmethacrylate and are present for antireflection purposes. Sandwiched between each window 10 and the corresponding patch antenna 2 on the dielectric substrate 3 is a dielectric coupling block of PT10 material (not shown). The holes 13 accommodate retaining screws (not shown).

Figure 3d shows a cross section of an assembly of the components of figures 3a, 3b and 3c. Dielectric coupling blocks 9 and their relationship with the other components are shown. The plane of the section passes through coaxial feedthroughs 5 with inner conductors 6 and outer shields 7. The inner conductors 6 are insulated from, and pass through, the brass backing plate 14 and dielectric substrate 3 and are connected to the planar feeds into the patch antennas (not shown). The outer shields 7 are connected to the brass backing plate 14 only.

Figure 4 shows a dielectric substrate 3 with an array 12 of patch antennas similar to that shown in figure 2a but with the ability to implement orthogonal planes of polarisation. This is achieved by including a second planar feed 8a on each patch antenna. Planar feeds 8 and 8a feed adjacent corners of each patch.

Figure 5 is a typical linear plot of the match which can be obtained from the type of antenna system described above. The vertical axis indicates power which is reflected back along the transmission line rather than being transmitted into free space. The diagram shows the variation of this power with signal frequency and a useful bandwidth of about 2 GHz at 20 dB.

Figure 6 shows typical E-plane and H-plane radiation patterns obtained from this type of antenna system for a signal frequency of 9.6 GHz.

CLAIMS

1. A dielectric resonator antenna system comprising

- a dielectric substrate sheet having opposing first and second surfaces; a patch antenna formed on the first surface, the patch antenna having a length that varies across the width of the patch such that a wide range of resonant frequencies can be stimulated therein,

- a ground plane formed on the second surface

- a dielectric coupling element adjacent to the first surface whose dielectric constant and thickness are such that radiation coupling to and from the probe is predominantly through itself.

2. The dielectric resonator antenna system of claim 1 where the patch antenna is square and corner fed.

3. The dielectric resonator antenna system of claims 1 or 2 with the additional feature of a second means for feeding signals to and, or from the patch antenna, the second means being arranged orthogonal to the first.

4. The dielectric resonator antenna system of any of the preceding claims with the additional feature of a dielectric matching element whose antireflection characteristics are optimised at a frequency which is slightly different from the minimum of the range of frequencies which may be stimulated in the patch antenna.

5. The dielectric resonator antenna system of any one of the preceding claims where the means for feeding signals to and, or from the patch antenna is via a coaxial feed through the groundplane and dielectric substrate.

6. The dielectric resonator antenna system of any one of the preceding claims formed into an array of patch antennae.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number
GB 9214151.4

Relevant Technical fields

(i) UK Cl (Edition K) H1Q (QKA,QDX)

(ii) Int Cl (Edition 5) H01Q 1/36, 1/38, 1/40, 9/04

Search Examiner
MISS J E EVANS

Databases (see over)
(i) UK Patent Office

(ii) ONLINE DATABASES: WPI

Date of Search
15 OCTOBER 1992

Documents considered relevant following a search in respect of claims 1 TO 6

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
Y	GB 2251340 A (GEC) figures 1 and 9-13	1-3 and 6
Y	GB 2248522 A (SEC OF STATE FOR DEFENCE) figures 1 and 4	1, 4 and 6
Y	US 4775866 (NIPPONDENSO) figure 1	1 and 3
Y	US 4326203 (U S NAVY) figure 18	1 and 2
Y	US 4067016 (U S NAVY) figures 1 to 5	1-3 and 5
Y	International Journal of Infra red and Millimetre Waves, 7, No 4, 1986, pp 550-570	1 and 5
Y	IEEE Transactions on Antennas and Propagation AP-31, No 3, May 1983, pp 406-412	1 and 5
Y	US 4012741 (BALL) figures 1 and 3	1 and 6

Categories of documents

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